2021 S4 Assignment 19A
Electromagnetic Induction - Answers

Note: **General approach** to electromagnetic induction phenomenon

Identify any relative motion between magnet and conductor
➔ <u>Rate of cutting</u> of magnetic field lines (or magnetic lines of force) by the conductor (e.g. coil or solenoid)
<mark>OR</mark>
<u>Rate of change</u> (increase or decrease) magnetic lines of force (or magnetic flux) linked to the conductor

➔ By <u>Faraday's law</u>, an e.m.f. is induced in the conductor (e.g. coil or solenoid)
➔ <u>Observation</u> of change in circuit (e.g. deflection in electrical meter, light bulb lights up, display on C.R.O.)
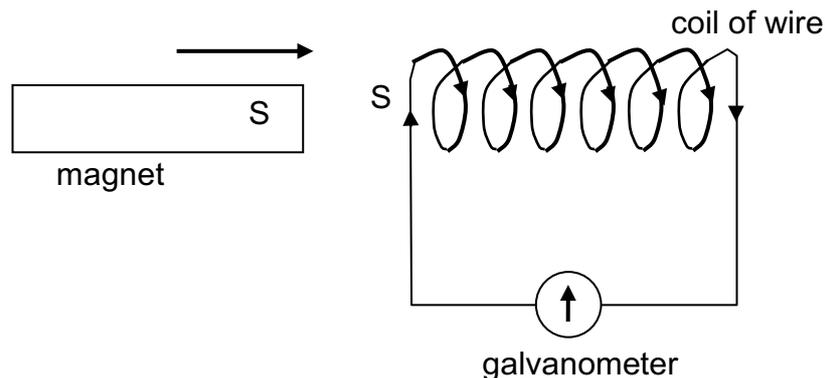
Note: Explain by applying a law means <u>paraphrasing</u> it suitably, not stating it.

1(a)   As the magnet moves into the coil, there is <u>cutting of magnetic field lines</u> by the coil

<mark>OR</mark> there is an <u>increase the magnetic flux linked to the coil</u>. *[not momentary change!]*

By <u>Faraday's Law</u>, an e.m.f is induced in the coil.

(b)

magnet

coil of wire

galvanometer

Correct direction of current in the coil

(c)   As the magnet moves into the coil, the induced e.m.f. in the coil <u>causes an induced current</u> to <u>flow in a direction to set up a S-pole on the left side of the coil</u> to <u>repel</u> (or oppose) the <u>motion of the magnet</u>, by <u>Lenz's Law</u>.

The <u>right hand grip rule</u> is used to deduce the current direction shown.

(d)   Any two ways:
    (1)   Move the magnet faster into the coil.
    (2)   Increase the number of turns in the coil.
    (3)   Use a stronger magnet.
    (4)   Insert a soft iron core in the coil (or wind the turns of the coil on a soft iron core) - note that this may prevent the magnet from entering the coil.

2(a)   When the magnet accelerates towards the solenoid, there is an <u>increasing rate of cutting of magnetic field lines by the solenoid</u>.
By <u>Faraday's law</u>, there is an <u>increasing e.m.f. induced in the solenoid</u> resulting in an <u>increase in the deflection of the galvanometer</u> in one direction.

(b)   The <u>rate of cutting of magnetic field lines</u> by the solenoid <u>decreases to zero</u>.
By Faraday's law, the <u>e.m.f. induced</u> in the solenoid <u>decreases to zero</u> as shown by the <u>deflection of the galvanometer decreasing to zero</u>.

3(a)   As the magnet falls towards the pipe, there is an <u>increasing rate of cutting of magnetic field lines by the copper pipe</u>.
By <u>Faraday's Law</u>, an <u>e.m.f. is induced in the conducting pipe</u>.

(b)   The induced e.m.f. causes <u>induced currents (or eddy currents) to flow</u> in the pipe.
By <u>Lenz's Law</u>, these induced currents would <u>flow in a direction to set up a magnetic field to oppose the motion of the falling magnet</u>. The net downwards force on the magnet decreases.Therefore, the magnet <mark>falls with a decreasing acceleration</mark>.

Note: *The magnet does not slow down, it continues to fall but at a slower rate.*

(c)   Copper is an <u>electrical conductor</u>, so there is induced e.m.f. which causes induced currents that <u>oppose the motion</u> of the falling magnet. Plastic is an <u>electrical insulator</u> that would <u>not cause electromagnetic induction</u> when the magnet falls through it, and <u>has no effect on the motion</u> of the magnet.
Hence the time taken to fall through the <u>copper pipe will be longer</u> than that of the plastic pipe.

4(a)   As the coil rotates, there is <u>rate of cutting of the magnetic field lines</u> of the permanent magnets <u>by the coil</u>.
By <u>Faraday's law</u>, an e.m.f. is induced in the coil.
<mark>OR</mark>
As the coil rotates, there is a <u>rate of change in the magnet flux</u> of the permanent magnets <u>linked to the coil</u>. By <u>Faraday's law</u>, an e.m.f. is induced in the coil.
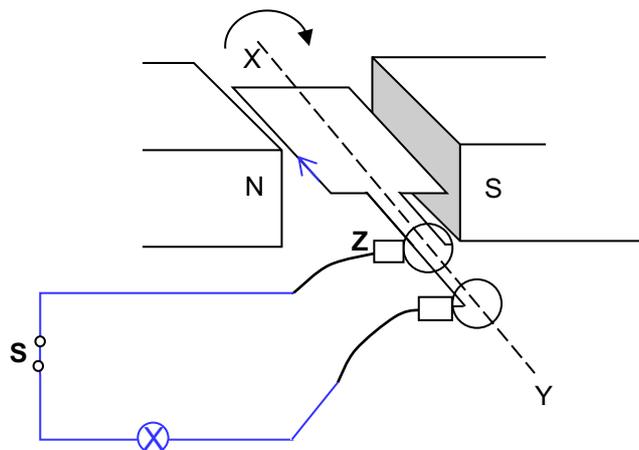
(b)(i)   external circuit with light bulb and switch

(ii)   direction of current shown above
polarity of Z is <u>positive</u>

(iii)   The magnetic field and direction of motion of the coil are given. Using <u>Fleming's right hand rule</u>, the direction of the induced current in the coil is deduced as shown above.
The <u>current</u> on the right side of the coil is <u>flowing out of the coil through the carbon brush at Z to the external circuit</u>. Hence **Z** is positive.

5(a)   Point **C**

This point represents the voltage when the coil is <u>moving towards the position</u> where its <u>plane is perpendicular to the magnetic field</u> (where the rate of cutting of magnetic flux is going to be minimum), i.e. the magnitude of the <u>induced e.m.f. is decreasing towards zero</u>.

(b)(i)   The <u>amplitude</u> of the induced voltage <u>would be doubled</u> and

the <u>frequency of the induced voltage would be doubled</u> or its <u>period is halved</u>.

Note: *This question does not require an explanation.*

(ii)